Exam 004: Electric Traction: AC induction Motor with SiC-based inverter and Thermal requirements

In electric traction systems with power electronic inverters based on IGBT as in Metro M6, measures are needed to efficiently control the AC electric traction motor to follow the required speed profiles. In this case -study, a scaled AC traction system with SiC inverter system is used to investigate the performance of the traction system and its control system.

The DC power supply, including overhead line, is simulated by means of a transformer fed diode rectifier and a 10mH reactance. The traction system itself is modelled by a DC-link capacitor (15000 µF), 3-leg inverter with 2-level configuration to compose an AC inverter. The AC traction motor is a squirrel-cage induction motor with standard three-phases, loaded with a DC generator or other means.

The students should address the following tasks.

1. Analyse, by means of Matlab simulation, the operation modes of the AC traction system (traction and braking) (4p);
2. Select the proper SiC devices or modules and their switching frequency to minimize the losses of the power semiconductors (3p);
3. Evaluate the V/F control system that is used to control the motor in 2 quadrants (4p);
4. Calculate the losses of the DC/AC SiC-inverter and losses of the induction motor (3p); Select the proper requirements for the thermal resistance for the cooling system so that the inverter can operate up to an ambient temperature of 40°C at full power; Estimate the energy saving compared to the IGBT-based inverter.
5. Quality of the simulations, in particular taking into account the non-linear behaviour taking into account the analysis of current and voltage harmonics as well as THD (3p);
6. Quality of the control system, with respect to the soft starting the traction system and preservation of the control dynamics (3p).

* Evaluation criteria are as follows: Quality of the mathematical models and the simulation models; Quality of transfer functions used for the control analysis; Quality of the proposed solutions.

Details on the simulation model

Power supply

Power supply network three phases 380 V, SC power: 30 MVA
Three-phase transformer:

- 380V
- Y connection
- Rated power: 20 kVA

Diode rectifier

- 6 diodes, bridge connected
- Rated current 200 A
- Output inductor: 10 mH, 100 A;

IGAT-based inverter

- Input DC-link capacitor: 15000 µF
- Semiconductor devices voltage rating: 1200 V
- Semiconductor devices current rating: 150-200 A
- Switching frequency: up to 20 kHz

19kW- induction motor

Rated power	*19 kW*	Stator leakage inductance (L_{ls})	*0.0018 H*
Rated line voltage	*400 V*	Rotor leakage inductance (L_{lr})	*0.0018 H*
Rated frequency	*50 Hz*	Rated Speed (N_r)	*1460 rpm*
Stator resistance (R_s)	*0.0629 Ω*	Moment of Inertia (J)	*0.2799 kg.m²*
Rotor resistance (R_r)	*0.1091Ω*	Friction Coefficient (B)	*0.0129 N.m.sec/r*
Mutual inductance (L_m)	*0.0408 H*	Pole Number (P)	*4*
R_{fe}	*213.2 Ω*	ξ	*0.85*

Control system

- PI current control systems (i.e. single loop or dual-loop)
- The load machine is controlled to simulate the vehicle dynamic behaviour.

Driving Cycle (*An Example for traction and load torques*):